Integrated Broadband Mobile System (IBMS) featuring Wireless ATM

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Abstract: *IBMS is a concept for future mobile communication systems to provide a large range of data rates with different degrees of mobility. The integration of heterogeneous services and communication systems requires a common Network Access and Connectivity CHannel (NACCH) for basic signaling to provide permanent network access. Smart Antennas are utilized to adaptively enable a trade-off between mobility and data rate.*

Keywords: *IBMS, System Concept, NACCH, Smart Antennas, Wireless ATM, HIPERLAN, OFDM, Broadband WLAN, Home Networks, Rate Fallback, Power Saving*

Introduction

Temporary wireless communication systems are designed for specific data rates and mobility support. Personal communication systems provide high mobility, at low data rates with limited potential services. Higher data rates up to 155 Mb/s will be supported by wireless ATM systems for users with limited mobility. Future demands for mobile communication systems will be dominated by the heterogeneity of broadband services which are to be supplied in inhouse and outdoor environments, simultaneously, with varying degrees of mobility. The objective of the Integrated Broadband Mobile System (IBMS) [1,2] is to provide a unified way for supporting a variety of communication classes ranging from high mobility with low data rates towards portability at high data rates. This requires the development of a uniform network structure, which also enables the integration of different communication systems, working at different frequencies. Research has been established on new emerging technologies like Smart Antennas, adaptive modulation and access techniques with an integrated view of signaling and protocols for wireless transmission. Figure 1 relates IBMS to other European research projects. IBMS is embedded in the ATMmobil research focus project.

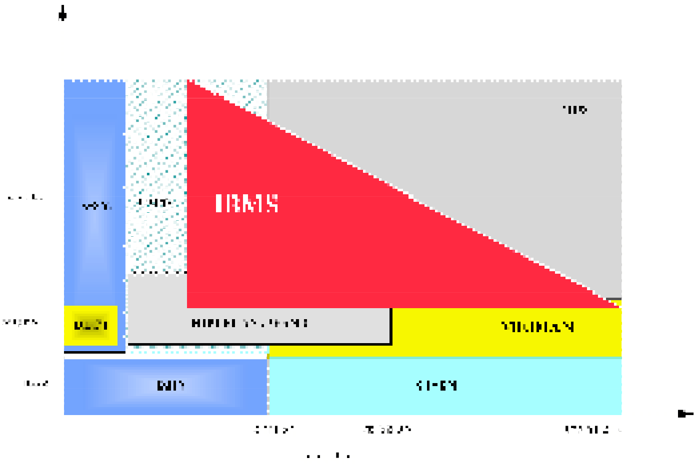

Figure 1: IBMS concept with respect to other European research projects.

System Concept

The design of an integrated communication system for heterogeneous services and terminals with different air interfaces and variable bit-rates requires a new network infrastructure. Figure 2 shows a hierarchical structure of Network Service Classes (NSC), which have been introduced [1] to support different Quality of Service (QoS) parameters with respect to mobility. Each NSC comprises a functional signaling set (depicted as circles in Figure 1) which is used for configuration of the particular NSC and selection of the appropriate Traffic CHannel (TCH).

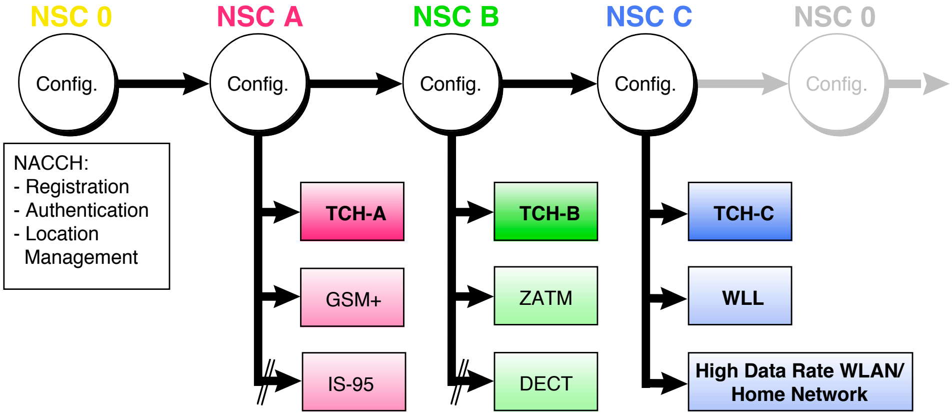

Figure 2: Hierarchical Structure of Network Service Classes (NSC).

NSC-0 comprises the basic signaling set of the common signaling channel (NACCH) used for registration, authentication, and location management. Additional network functions in higher-layered NSCs (A-C) provide a wide range of data rates at different degrees of mobility. A particular NSC inherits all functionalities of subordinated NSCs. In addition, sub-hierarchical network structures (e.g. inhouse overlay networks) can attach to NSC-C as another NSC-0 in order to integrate the inhouse and outdoor environment. Providing global coverage, the fundamental NACCH for system access and signaling is available for all mobile users independent from their respective mobility. Selecting the appropriate NSC enforces the trade-off between data rate and mobility (Figure 3). The hierarchical network structure supports rate fallback, which is another key feature of IBMS. If a required QoS cannot be maintained, the system falls back to lower NSCs without loosing connection and automatically switches back to the original NSC if the necessary channel characteristics are met. Since higher NSCs exploit the frequency/space capacity of the network more efficiently, connections of lower NSCs shall be carried along in higher NSCs when channel conditions are appropriate.

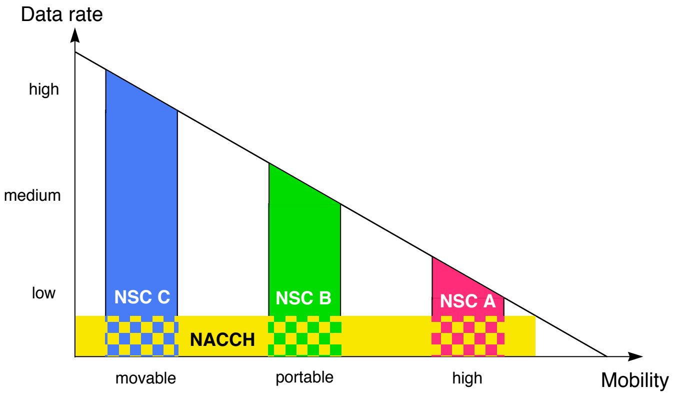

Figure 3: Trade-off between Data Rate and Mobility for different NSCs and NACCH.

Furthermore, IBMS will allow switching to different communication systems (Figure 2), thus enabling the integration of proprietary system concepts. The transition is either controlled by IBMS within NSC-0 and permits re-entry or a complete inter-system handover, which is currently discussed within the MMITS Forum.

Network Access and Connectivity Channel (NACCH)

Integral part of the IBMS concept is a common signaling channel for network access and connectivity (NACCH). It is narrowband with respect to its data rate and constantly available in order to guarantee permanent network access and basic signaling functions. The physical NACCH implementation depends on the respective environment (e.g. different frequencies or even infrared for inhouse networks) while the functional specification is independent from the platform used. A scaleable implementation has been developed for OFDM based modems [3], which allows integration of FSK and OFDM modems in the same frequency band. The NACCH can also be used to support efficient power saving techniques. In order to take full advantage of this property, three operating modes have been designed [3], introducing a Stand-by Alert mode. Since all required signaling is done using the NACCH, power consumption will be reduced during connections when no data is currently being transmitted. This feature can be used effectively for ATM based multimedia services. In order to fully support the integration of future systems towards software radio telecommunications [4], a minimum possible functional set has to be identified for standardization procedures.

Smart Antennas

The trade-off between mobility and data rate could be realized using an overlay network structure with micro-cells and pico-cells. The smaller the cell area gets, the more the granted mobility decreases along with an increased possible data rate. However, in IBMS we follow another approach. Smart Antennas are used to effectively improve the radio channel properties and enable adaptive higher modulation techniques for increased transmission data rates by means of enhanced SINR and reduced delay spread. Furthermore, SDMA can be applied to increase the network capacity. Several channel models have been investigated to demonstrate these effects. Measurements will be carried out to verify these results. Figure 4 shows three different NSCs with their intended data rates and the accordingly required antenna arrangements, the basestation (BS) being on the left, and the mobile station (MS) on the right side. In NSC-A, BS and MS use antennas with omnidirectional patterns. For implementation of NSC-B, the BS gets a directed (smart) antenna, and in NSC-C, both the BS and the MS have directed ones.

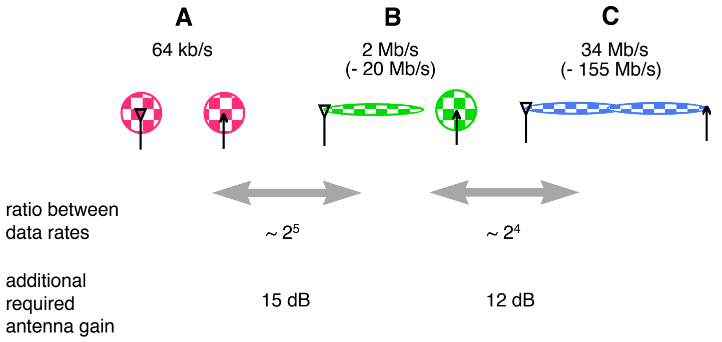

Figure 4: Smart Antennas used in the IBMS concept to enable proposed NSCs.

As part of the idea behind IBMS, devices of all NSCs shall transmit the same maximum power level, using the same channel bandwidth. Since the power spectral density (PSD) of the transmitted signal gets weaker with increasing data rate, the idea is that this loss in PSD shall be compensated for by the antenna gain of the Smart Antennas. As apparent from Figure 4, the ratio between the data rates of two adjacent NSCs is about 2^4 to 2^5, which requires antenna gains of the same order of magnitude, i.e. about 12 to 15 dB. After consideration of possible interference situations we are currently investigating a scenario where users of each NSC span the whole available bandwidth of approximately 20 - 25 MHz. One possible solution will be using Multi-Carrier CDMA for TCH-A, while CDMA and SDMA (using Smart Antennas) will be used for TCH-B, and TCH-C will use TDMA and SDMA. For TCH-C, use of OFDM with appropriate subcarrier modulation is intended.

Protocol Issues

Some recent research deals with protocol issues and proposes the major functional layers of the network. The incorporated wireless channel specific layers for medium access, data link and wireless control are discussed in [5]. We outline the following from a research point of view, namely medium access, power saving and handover control.

The system design of IBMS provides simultaneous usage of different types of NSCs with dedicated optimum hardware configurations. Obviously several mechanisms should be used for medium access control. Since both, NSC-A and NSC-B utilize CDMA for media access, they can in principle use the same MAC protocol. However, NSC-B additionally uses SDMA, which requires a resource control to enable intracell handover. This is generally needed for implementation of SDMA techniques if the dedicated antenna patterns of two mobiles using the same code/frequency cannot be spatially separated anymore. Furthermore, SDMA implies the parallel handling of several MAC entities, i.e. for every antenna pattern and/or code there has to be a particular MAC entity. A completely different MAC is needed for NSC-C which utilizes a combination of SDMA and TDMA. Channel bundling of several NSC-A and NSC-B channels shall be permitted for a gradual data rate adaptation. In addition, TDMA permits sharing of NSC-C channels among different mobiles. A sophisticated resource control mechanism needs to be realized in order to handle these problems. Several MAC protocols (e.g. RATM [6], DSA++ [7], RNET [8]) have been published for TDMA based systems. New mechanisms need to be developed in the scope of this project for a combination of TDMA and SDMA.

The medium access level can also be used to fine-tune power saving in addition to system power saving. In [9] it is shown, that significant improvements can be achieved in the power budget of a wireless network interface card. The power saving mechanism design affects packet delay, buffer size requirements and additional load through signaling data. Various power saving design options such as in/outband signaling, centralized/distributed buffering and centralized/distributed synchronization exist for medium access. These will be explored in the course of the project.

Handover control is needed for terminal migration from inhouse and outdoor environments. This is another critical protocol issue, which will be realized by dynamic re-routing of a set of Virtual Circuits (VC). In the IBMS context one can identify different mobility related QoS requirements for the NSCs. Transition between wireless cells leads to service disruption, cell loss, delay, and jitter. Proposed handover schemes (e.g. path extension or re-routing) are currently beeing discussed in the ATM Forum and will be applied to satisfy QoS requirements. In a picocellular in-house environment with frequent handover events and strict timing constraints, a sophisticated multicast-based handover scheme [10] will be used in order to minimize the overall service interruption as shown in Figure 5.

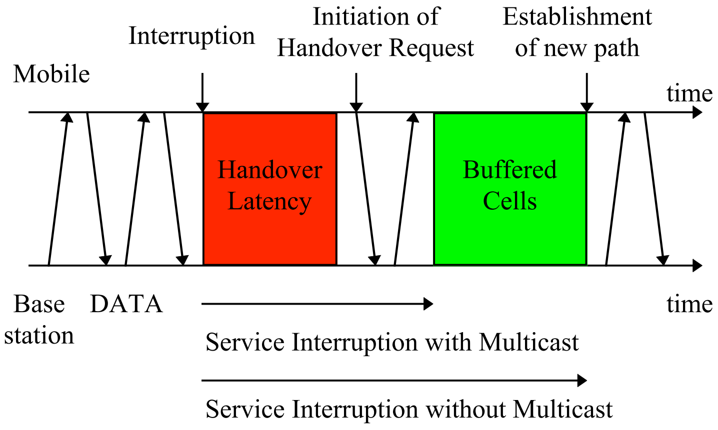

Figure 5: Gain of Multicast-based Handover.

Radio Modem

The work on the radio modem includes issues on efficient modulation, access and coding techniques related to the physical channel for high data rate applications as well as a work on advanced RF technologies. In order to support different service classes and QoS parameters, adaptive baseband processing (modulation, coding) and separate signaling are investigated. Multicarrier OFDM is proposed to be used in the radio air interface for the inhouse and outdoor environment in the 24 GHz and 5 GHz frequency range, respectively. Current research on OFDM covers the development of advanced synchronization algorithms and subsystems for implementation of both, adaptive modulation of the orthogonal subcarriers and adaptive coding rate. The influence of nonlinear power amplification, as well as issues of peak to average power ratio reduction will also be treated. RF related work includes the investigation of advanced RF technologies: low cost high frequency direct conversion systems and low cost planar printed antennas. Different IR approaches are investigated for inhouse environments.

In order to support the specified NSCs, rate fallback, or recovery under severe transmission channel conditions, a flexible access and modulation scheme is required. OFDM has been considered for the modulation scheme because of its great flexibility to support narrowband as well as broadband transmission, simultaneously. At the same time it copes well with the impairments of a multipath propagation environment.

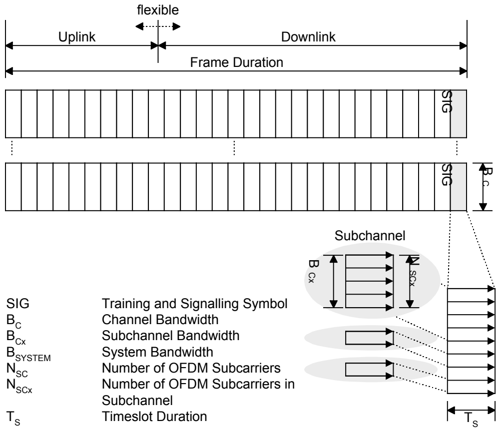

Figure 6a: An Adaptive TDD OFDM Access Scheme (ATDD-OFDM).

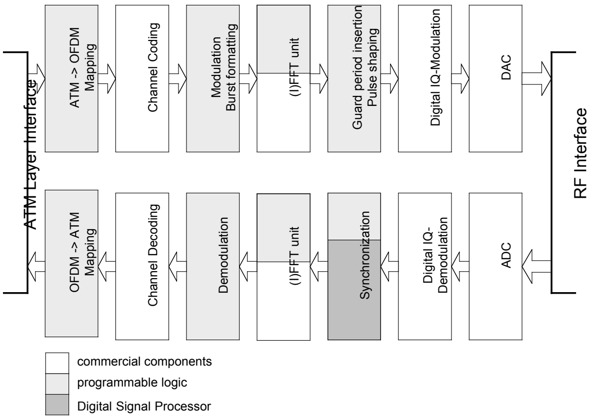

Figure 6b: Realization approach of the demonstrator baseband block.

Figure 6a shows the proposed adaptive Time Division Duplex (TDD) access scheme realizing asymmetric up- and downlink bandwidth through flexible time slot assignment. The overall system bandwidth is divided into several channels each of which consists of different orthogonal subchannels. A subchannel should be able to provide the most elementary communication service targeted for the system (e.g. voice service) or possibly the common signaling channel. Larger bandwidth requirements can be addressed by merging several orthogonal subchannels. According to the working scenarios at 24 GHz it should be possible to have frequency re-use even for close cells. That would allow merging of more frequency channels within one cell in order to obtain peak assigned bandwidths. This concept should allow net data transmission up to 150 Mbit/s.

The modem demonstrator will realize the proof of the concept for a simplex data transmission over a 24 GHz and partly over a 5 GHz channel, related to the typical environment scenario and using advanced antennas [11-13]. It will include a hardware implementation of a high data rate OFDM transmission system having bandwidth of about 20 MHz and raw data rates up to 80 Mbit/s. In Figure 6b the realization approach of the high data rate baseband block of the flexible demonstration test bed is presented.

Conclusion

The proposed concept will contribute to the further integration of different communication systems towards a global mobile communication system. We will support and integrate ongoing efforts and standardization of future global communication systems like UMTS, wireless LAN and home high data rate network approaches utilizing ATM backbone in the mm-wave range, as well as HIPERLAN-like systems.

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